XIX. *Observations on the Growth and Habits of the Stick Insect,* Caurausius morosus, *Br.; intended as a contribution towards a knowledge of variation in an organism which reproduces itself by the parthenogenetic method.*

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[Read October 18th, 1916.]

INTRODUCTION.

The stick insects dealt with in this paper are descended from a few specimens given me some years ago by Dr. Clubb, Director of the Liverpool Museums. With the exception of three almost black specimens, they are all the progeny of one female hatched out of an egg from the original lot. The three black specimens are the offspring of some of the others received from Dr. Clubb.

The young and fully grown insects were kept under observation in inverted glass bell-jars of various sizes, each one furnished with a small glass or pot receptacle filled with water and well-washed sea-sand, in which were placed the food-plant cuttings. I had at times over forty of these jars in use, containing altogether some 400 specimens. The temperature of the room in which they were kept was regulated as much as possible between 56° F. and 64° F., although it did fall to 52° F. during some very severe cold days in the first winter.

As regards the measurements made, it is as well to note that it is easier to measure dead than living specimens, and in a few cases where it was not possible to measure the living specimens with approximate accuracy these specimens have not been included in the series commented on.

The reference or series numbers given in the tables are given consecutively—there has been no picking and choosing—and the gaps indicate other groups, or series, or egg lots, etc., undergoing observation for other purposes, or may be traced to specimens which have dropped out through death or the development of some malformation, or on account of having been killed off as not further required, etc.

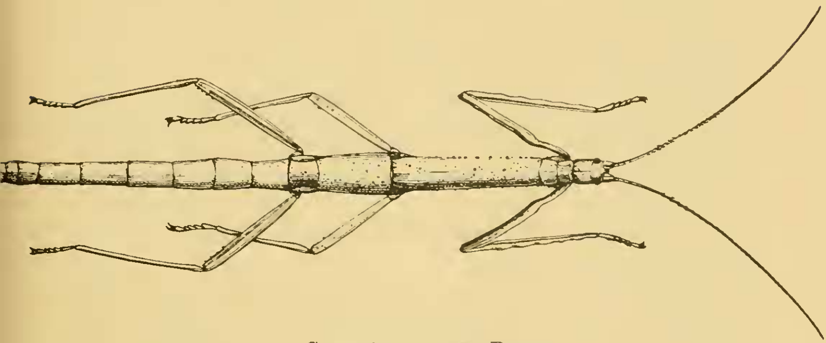
I wish to express my sincere thanks to Dr. Walter M. Tattersall and Dr. A. D. Imms for valuable assistance in preparing this paper.

As regards the position of *Carausius morosus* among the Phasmids, the late Mr. Meade-Waldo kindly wrote me: "*Carausius*, Stal., Rec. Orth. iii, p. 8 (1875)—Type *C. strumosus*, Stal., from Java. *C. morosus*, Brunner v. Wattenwyl, the species with which we are concerned, was described for the first time in Die Insekten-familie der Phasmiden, Lief 2, p. 268 (1907), and is thus not included in Kirby's Catalogue of Orthoptera. There are no synonyms to *C. morosus*, though some authors have considered the genera *Carausius* and *Dixippus* as the same. Kirby in his catalogue gives *Dixippus*, Stal., as a synonym of *Lonchodes*. Brunner divides the Phasmidae into two large groups: *Phasmidae areolatae* and *Phasmidae anareolatae*—

Tribus 1, *Clitumini.*
Tribus 2, *Lonchodini*, to which *Carausius* belongs.
Tribus 3, *Bacunculini.*

These three tribes are distinguished from the three other tribes in this group by the short median segment. All the *Lonchodini* are Asiatic or Australian species. The nearest ally to *Carausius* is *Dixippus*, which Brunner separates as follows—

Carausius—mesosternum longitudinally carinate.
Dixippus—mesosternum not carinate."



Carausius morosus, Br.

General Note.

During the daytime the nymphs and insects are lethargic; lie about in every conceivable attitude with their appendages generally more or less parallel with the body, unless their position requires a leg or two differently placed for support. They are not easily roused, and when roused do not attempt to run away for more than about a couple of decimetres. They look more like portions of leaf-stems or twigs, on which they are more difficult to distinguish than at night when their appendages are in full play. Quite young nymphs prefer the underside of the leaf to rest on. They frequently hang together closely packed.

When handled they often feign death, and have a knack of slipping away backwards out of one's hand, while in falling their claws seem able to catch at almost anything. Their pads appear to assist them to walk and climb on fairly smooth surfaces, but I do not think this ability to be a case of suction, for if placed on a piece of plate glass, the surface of which has been well washed with water and then with alcohol, and the glass be tilted, they very quickly fall off. In their declining days they frequently lose the use of their claws, and then hang on by their elbows.

Colour.

The colour was generally green or fawn, often speckled and varied considerably in different insects, so that pale green or olive, light green, dark green, greenish fawn, fawn, dark fawn and reddish fawn were common enough.* Dark brown (almost black) is rare.

At birth the insects are a greenish brown, which changes to green or olive or fawn at the successive moults. After the colour is once pronounced there is hardly any change, thus of 26 mature insects under observation under the same conditions for 11 weeks, 1 changed from reddish fawn to darkish fawn, 1 from lighter to darker green, and 2 from olive to fawn, 19 remained the same colour as when first observed. This was the only special observation I took on change in colour. Three died (having finished egg-dropping).

Three dark brown, nearly black specimens came from normal-coloured parents. Their eggs produced 1237 nymphs, and 467 of these grew to maturity with the usual olive, green or fawn colouring. I had not accommodation to rear the rest, but I ascertained later that if the colour is to be brown it shows itself already at the 1st ecdysis. Altogether I obtained 8 dark brown specimens, and all these finished by becoming nearly black.

Schleip † found the darker insects shorter than the green ones, and gives the average length of ten dark red or black insects as 69·3 mm., of ten yellowish-red insects as 74·6 mm., and of ten green ones as 76·3 mm. I did not find this so;

* The range of colours therefore agrees closely with that of MacBride and Jackson ("The Inheritance of Colour in the Stick Insect, *C. morosus*," Proc. Roy. Soc., Ser. B, vol. 89, p. 109). J. C. Fryer illustrates two specimens of female *Clitumnus* (? *cuniculus*), one of which is a light fawn and the other a pale green or olive (Journ. of Genetics, iii, Sept. 2, 1913). Curiously enough, H. Blanc speaks of the single colour (*homochromie*) of *Dixippus morosus* (Bull. Soc. Vaud. Lausanne, 5 Ser. xlix, No. 179, p. xxv).

† Waldemar Schleip (Freiburg in Br.), Der Farbenwechsel von Dixippus morosus (Phasm). Zool. Jahrb. Abt. f. Allgem. Zool. u. Phys. d. Tiere, xxx, 1911, p. 78. He treats *Dixippus morosus* as the same as *Carausius morosus*, p. 46.

my shortest black measured 69 mm., and the two other blacks measured 74 and 78 mm. respectively (the average of 34 specimens from one parent being 80·1 mm.). I did not get the gradations in colour up to dark brown or black which Schleip shows on his coloured plate—in fact, between the dark brown (almost black) and the darkest fawn there was a big gap.

Incubation-box.

The eggs for incubation were placed in small glass-capped circular card-board boxes, with a thin layer of sand on the bottom. The sides were perforated by means of pins, and the boxes numbered on the inside (*not* on the lids). These boxes were placed in rows in a shallow wooden box (an old chocolate manufacturer's packing-box), the necessary moisture being provided by wet folds of clean blotting-paper well soaked afresh daily. The wooden box being badly made with an ill-fitting lid allowed amply for the circulation of the air.

Incubation.

In the incubation-boxes the incubation varies from 137 days to 297 days, thus covering an extreme range of 160 days. Those nymphs which hatched out up to 254 days' incubation were healthy and apparently in normal condition, but one which hatched out at the end of 297 days was very feeble, drank sparingly, and, although it was ready for a drink every one of the 6 days it lived, its abdomen remained contracted laterally and it did not eat at all, while usually about 50% have commenced eating on the third day after hatching out.

The accompanying table shows that more than 50% of

Table I.—No. of Days of Incubation.

Days.	No. Hatched.	Percent. Hatched.	Days.	No. Hatched.	Percent. Hatched.
137–140	7	1·7	231–240	1	0·2
141–150	131	31·8	241–250	1	0·2
151–160	86	20·9	251–260	1	0·2
161–170	42	10·2	261–270	0	—
171–180	42	10·2	271–280	0	—
181–190	49	11·9	281–290	0	—
191–200	30	7·3	291–300	1	0·2
201–210	10	2·4			
211–220	9	2·2	Total .	412	99·9
221–230	2	0·5			

the nymphs are hatched out after 141 to 160 days' incubation, and a further 32% fairly evenly distributed in the next 30 days (161 to 190 days), after which there is a considerable drop.

The variation in the number of days required for incubation by eggs dropped during 24 consecutive hours by any one individual insect is great, the range varying from 6 to 92 days. I am unable to account for this. I do not think it to be due to unsuitable, *i. e.* to too low a temperature, as the nymphs and insects thrive well at 15° C. (59° F.). Nor do I think it due to want of moisture, for of 71 unhatched eggs examined from 421–580 days after having been dropped, in 67 (= 94%) the contents were still quite moist. It is, generally speaking, the last nymph to emerge which makes the big jump in the range. I have not made any experiment to ascertain whether the extreme range is due to dryness, but H. H. P. and H. C. Severin have shown that dryness at the time of hatching with *Diapheromera femorata*, Say, has a marked retarding effect on the emergence of the nymph from the egg (Jour. Econ. Ent. 1910, p. 481).

Table II.—Range of Incubation of Eggs dropped in 24 Hours by Individual Insects.

Series No.*	Eggs in 24 Hours.	Days of Incubation.									Range in Days.
24	5	163	170	177	192	206					43
25	3	166	168	176							10
26	4	176	181	186	210						34
27	4	179	201	212	227						48
28	4	189	208	217	246						57
29	6	184	192	194	196	198	198				14
30	8	178	182	182	183	183	192	197	198		20
33	5	186	187	189	193	195					9
34	9	169	177	178	180	181	183	184	188	189	20
35	9	182	185	185	185	192	192	194	196	207	25
36	5	186	189	194	200	201					15
37	6	190	198	199	203	214	240				50
59	8	162	176	181	183	183	188	192	254		92
104	8	144	145	148	148	148	149	150	150		6
107	6	143	144	147	150	152	162				19
146	9	146	146	147	147	152	153	157	157	217	71

* Only a portion of those observed are given, but sufficient to give a general idea of the results.

Incubation under Diverse Conditions.

In order to test the method of incubation above described I experimented as follows :—Three lots of eggs were taken, which had been dropped by the same set of insects in the same twenty-four hours on three different occasions. One lot was placed in the usual hatching-box (B) just described, the second lot on the surface of sand (S), and the third lot on the surface of mould (soil) (M). Moisture was conveyed to the sand and mould by occasional light sprinkling, but mostly from below by means of a dipper. In the course of the incubation some of the eggs sank below the surface of the sand and mould. The nymphs from the sand and mould had, on emergence, access to water, but those from the box had not, and probably in consequence of this we find the box produced on an average shorter nymphs than the sand and mould, thus: M's average = 12·4 mm., S's = 11·9 mm., and B's 11·2 mm., but, in view of the results of observations on the extension of nymphs after hatching out, this is of little importance.

In so far as duration of incubation is concerned (Table III) the mould gave the quickest results, the nymphs hatching out on an average in 124 days with a range of 31 days (115–146), against the sand's average of 146 days with a range of 54 days (131–185), and the box's average of 151 days with a range of 31 days (141–172).

Table III.—Incubation under divers Conditions.

Species number	153	157	158
Where placed	Hatching-box	Sand	Mould
Quantity of eggs under observation	62	62	63
Total weight of eggs—gramms	·345	·311	·322
Average weight of eggs—millegrams	5·569	5·182	5·511
Period of incubation—days	141–172	131–185	115–146
Range of incubation—days	31	54	31
Average No. of incubation days	151	146	124
Total No. of eggs hatched	58	48	46
Percentage of eggs hatched	93·5	77·4	73·2
Total No. of fertile eggs	61	58	50
Percentage of fertile eggs	98·4	93·5	79·4
Percentage of fertile eggs hatched	95·1	82·8	92
Average length of nymphs when hatched	11·4	11·9	12·4
Change in outside appearance of shell	None	Slight	Marked

As regards the quantity of fertile eggs hatched out, the highest percentage was reached from the box, thus: B = 95·1%, M = 92%, and S = 82·8%.

In this experiment in no case was any nymph found to have succumbed through inability to emerge completely after once breaking through, as happens occasionally to the extent of about five per thousand in the usual incubating-box arrangements.

The fact that on the mould the incubation proceeded quickest would tend to show that it is the best of the three media, for, in Nature, the quicker this process goes on the less risk to the embryo—the lesser number hatched out being a sacrifice to the safety of the existence of the species.

Whether the corrosion, if I may so call it, of the eggs from the mould has anything to do with lowering the percentage of hatching out I am unable to say, but it would appear that the natural risks being overcome or reduced to a minimum in the box incubation, that method is the best for laboratory experiment.

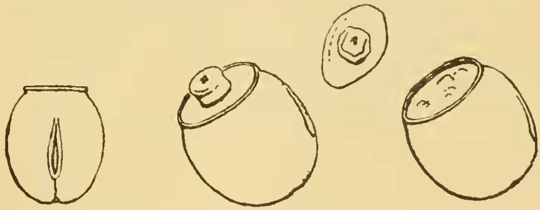
Parthenogenesis.

These stick insects belong to a Family in which parthenogenesis appears to be the rule, and my experience with them bears out the existence of the general law. The female from which I reared 354 insects up to the egg-bearing stage may or may not have been fertilised by a male. Her offspring were allowed to mix freely with one another until the last ecdysis was reached, when they were successively segregated, and every one of these which reached maturity dropped eggs. The assumption is, that there was consequently no male amongst them. Subsequently I separated 34 larvae (offshoots of some of the 354) on hatching out, and these with one exception all turned out egg-bearers. The one exception, No. 40, had a malformation at the penultimate abdominal segment, and took 170 days to get through the nymph stadia, instead of the average 136 days. It was a poor eater, consuming about one-sixth of the food consumed by the others, and remained thin and lethargic to the end.

A Male.

I had one other non-egg-producer, a descendant of one of Dr. Clubb's lot, which turned out to be a male. Dr. Imms dissected it, and found " well-developed reproductive organs. The latter appeared to be functional and showed no sign of degeneration. I made a preparation of the contents of the testes, and found that spermatozoa were present in various stages of development, but the number of mature ones was relatively small. The vesiculae seminales were large and filled with a thick fluid. They contained, however, scarcely any spermatozoa. Judged from these facts the example was not yet fully mature." This specimen had not increased in size for over five months, and, with the small quantity of mature spermatozoa present, the suggestion of a possible degeneration having taken place occurs to one.*

Its form and slow growth induced me to separate it from the others, not that I thought it a male, but because it was different from the others. Its noticeable difference consisted in the longer proportion of its legs to its body than is the case with females.



Egg capsule of *C. morosus*, with and without lid.

Form, Size and Weight of Eggs.

The egg is contained in a capsule, the general shape of which is somewhat similar to a flattened cask, and having consequently an oval cross-section, flat at one pole and semispherical at the other. The flat end is covered by a lid, which consists of a platform with encircling ridge, and in the middle there is a light buff-coloured glossy cap. This cap is only partially perforated in the centre; the apparent hole is closed by a very thin skin, the use of which may be to admit air and moisture by endosmosis, for the

* "Mr. K. G. Blair exhibited a ♂ and two ♀♀ of a stick insect (? *Lonchodes*, sp.) which is usually parthenogenetic, the ♂ being excessively rare, and which he had bred for several generations without any specimen of this sex appearing (Trans. Entom. Soc. London, 1911)." In Proc. Zool. Soc. 1915, p. 155, Miss A. C. Jackson mentions that out of about 3000 *C. morosus* which she reared, seven males were identified.

chorion itself seems to be too solid and close-grained to admit either. The capsule rounds off immediately below the lid. On one of the flattened edges between the middle and the spherical pole is the mark of the ovary attachment, in the form of a dark narrow ridge completely encircled by another ridge, the whole about 1 mm. long.* Not infrequently a lid or cap is found at both poles, but the one cap is then generally more or less malformed and the platform hardly discernible. So far none of the eggs with opposing capsules have hatched out, nor is it likely that they will do. Where these opposing processes exist the mark of the ovary attachment is not clear. I have one egg with two caps on one and the same platform.

The total length of the egg capsules varies generally from 2·7 to 3·2 mm., 504 specimens measured giving an average length of 2·8 mm. Some capsules are as short as 1·2 mm., but are rarely met with, and anything under 2·6 mm. does not hatch out.

The outer surface of the capsule is a dull brown grey, rough to the touch, and under the microscope shows convolutions somewhat similar to those of a pancreas. This

Table IV.—Weight of Eggs.

Quantity weighed.	Total weight in Gramms.	Average Weight in Millegramms.	
62	·345	5·569	Each lot collected represents the number of eggs dropped during the previous 24 hours and was weighed the same day.
63	·322	5·511	
77	·4	5·195	
29	·149	5·138	
66	·342	5·55	
62	·311	5·182	
40	·222	5·1	Weighed by C. Fielding: From my stick insects.
100	·51	5·01	From others.
190	1·035	5·446	4 days' collection.
689	3·636	5·277	

* The egg is almost identical externally with that of *Carausius hilaris*, Br., which is, however, smaller and apparently more oval in shape. See Amelie Elkind, "Les Tubes ovariques et l'ovogène chez Carausius hilaris," Br. Lausanne, 1915, p. 14.

C. morosus and *C. hilaris* differ as follows: *C. morosus* has the anal segment truncate, with only a slight triangular emargination; *C. hilaris* has the anal segment produced into two lobes with the apex obtuse (Brunner and Redtenbacher, Monograph of Phasmids, R.M.-W.).

roughness is probably the cause of the capsule's easy adherence to any object however smooth if the surface be only slightly moist. The inside of the capsule is, on the other hand, very glossy, and under the microscope shows complex reticulations.

The weights are of eggs dropped by full-grown insects of all ages after the sixth ecdysis.

Six eggs dropped by the undersized full-grown insect, No. 159, weighed ·023 gr., or on average 3·833 milligrams.

Fertility of the Eggs.

In determining the quantity of fertile eggs dropped by the individual insect under observation all the remaining eggs were, several months after the date of the last hatching out of the others, broken open and examined. The number of eggs found to have been fertile, but unhatched, were then added to the number which hatched out, and the total treated as the quantity of fertile eggs. The following table gives the results of the examination of four batches of eggs.

Eggs dropped at the commencement are as fertile as those dropped at a later stage; 24 eggs dropped in the first week by various beginners all hatched out, and out of another lot of 26 first eggs dropped by any insects, 22 hatched out = 84·6%. Of 2 eggs, the last dropped by different insects, 1 hatched out.

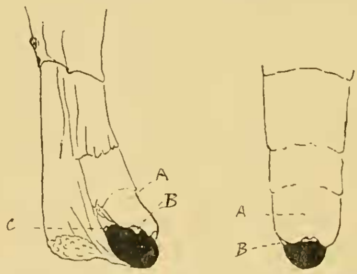
Table V.—Fertility of the Eggs.

	Original Specimen.	No. 38.	No. 39.	No. 42.	Total.
Quantity of eggs hatched . .	428	450	405	382	1665
Found fertile but not hatched	18	24	46	2	90
Total fertile eggs	446	474	451	384	1755
Unfertile eggs	114	100	107	78	399
Total eggs dropped . . .	560	574	558	462	2154
Percentage of fertile eggs . .	79	82·6	80·8	83·1	81·5

Oviposition.

After the sixth or last ecdysis, from which proceeding the insect emerges very attenuated, the same as after every ecdysis, the ovaries begin to develop.

I have only seen the egg produced on three occasions. The emergence was slow and deliberate—it was, in fact, mere egg *dropping*. On one of these occasions I happened to notice the egg just as it was about halfway out. This was at 9.15 a.m. At 11.2 a.m. the egg *dropped* to the ground. There seems to be a special process, the function of which is to retard the ejection. I attempted in another way to ascertain whether there was any quick expulsion or shooting out by placing the insects on top of a rod amongst plenty of food in the centre of a large shallow box, the bottom of which was covered with a layer of white sand. The sand was intended to prevent any rebound when the egg reached the floor. But the experiment was not a success in so far as conclusive proof was concerned, for although the few eggs dropped were found lying within two decimetres of the rod's socket, the insects themselves were continually escaping. The eggs emerge with the cap-



A and B Portions of Last Abdominal Tergum.
C Special Egg-holding Process.
D Egg lid.

sule end pointing inwards. The insect makes no provision whatever for the care of its young.

Observations were made on 39 specimens to ascertain how soon eggs are dropped after the last ecdysis, the sixth. The result expressed in days is as follows: 18, 24, 18, 30, 16, 20, 19, 18, 20, 18, 16, 15, 15, 16, 17, 15, 12, 17, 14, 13, 15, 16, 16, 19, 17, 16, 19, 16, 15, 20, 16, 13, 18, 14, 17, 16, 15, 15, 14. Eliminating the record of one insect which dropped her egg 30 days after the last ecdysis, for her whole period of development was abnormal, we find the dropping of eggs takes place from 12 to 24 days after the last ecdysis, giving a range of 12 days with an average of 16·5 days.

Abnormalities.

The results of the observations on 32 insects, as regards their duration of life and egg-production, are given in

Table VI. This table, in which the insects are arranged according to their length, gives the total egg-production per insect, the average daily production per insect, and the average production per millimetre length of the insect. It also gives the days lived in the First Period of life or that of growth from hatching out to, and inclusive of, the last moult, and the Second Period, or that of reproduction and decay, from the last moult to death.

Before going into details it may be as well to point out the peculiarities of some of the insects which, if abnormal, may have affected their duration of life and egg-production.

The "Original" with 346 days of life was a very good egg-producer, but with a low average per day. Her life may have been prolonged by the fact that the temperature of the room in which she was observed was not kept up to an average of over 16° C., as I was then under the impression that these stick insects were European and not Indian. But this explanation (of more than the normal number of days lived in the Second Period) cannot hold good for No. Ex. 18, her grand-daughter, which suffered from an external blood clot * and lived the longest of any in this period. No. 22 had two constricted abdominal segments. No. 159 was anomalously short, being 62 mm. long, which is very much below the average length of the fifth moult; whether she had grown with less than the usual average increase at each ecdysis, or had not completed the whole six, I am unable to say; but it is quite likely she had only moulted five times, for dissection shows eggs already formed in stick insects which had not yet passed the last moult. No. 42 was brown, almost black, and not a descendant of the "Original," but belonged to the same lot; she lived 29 days after dropping her last egg. No. 94, which was also under observation for food consumption and ate about 20% less food per day than the others, had a short life and a low egg-production. No. 89 lived 28 days after dropping her last egg. No. 38, like No. 42, was also nearly black, and not a descendant of the "Original," but she was a better egg-producer and long-lived in the Second Period; the same applies to No. 39. No. 83 was only a tolerable

* Exudation of blood from the thorax in Orthoptera has been observed by Ch. Hollande and has been named by him Autohemorrhée; he ascribes it to a break caused by pressure on the small exsertile chitinous vesicles which are not provided with retractile muscles (Archiv. d'Anatomie Microscopique, xiii, 1911–12, p. 299).

TABLE VI.

Series Number.	Oviposition of 32 Insects summarised in 26 consecutive Fifteen-Day Spells from the Last (Sixth) Ecdysis to death, *i.e.* During the Second Period of the Insect's Life.																										Duration of Life in Days.			No. of Eggs per Day in II Per.	Length of Insect in mm.	No. of Eggs per mm. Length of Insect.	Max. No. of Eggs.	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	Total No. of Eggs.	I Per. Hatching VI. Ecd.	II Per. VI. Ecd. to Death.	Total.				In 1 Day.	In 3 Days.
Orig'l	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	560	—	346	—	1·62	—	—	—	—
Ex. 18	—	2	2	4	2	4	—	3	—	3	—	2	1	2	—	2	1	4	1	2	1	—	—	—	—	2	38 [1]	—	392	—	·09	—	—	3	5
Ex. 22	—	28	23	24	26	9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	110 [2]	—	84	—	1·31	—	—	3	4
159	—	29	26	25	22	17	9	17	17	12	10	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	186 [3]	—	177	—	1·04	62	3	5	7
42	—	15	32	33	36	36	29	23	32	28	33	36	30	41	34	16	6	2	—	—	—	—	—	—	—	—	462	—	291	—	1·59	69	6·7	6	11
94	2	42	34	33	30	38	28	19	25	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	253	133	142	275	1·78	70	3·6	7	12
89	—	39	42	44	49	52	50	52	52	51	44	32	29	26	20	12	1	—	—	—	—	—	—	—	—	—	595	133	269	402	2·21	73	8·2	8	17
38	—	26	30	27	38	44	42	35	27	36	34	35	30	23	35	44	25	12	11	11	5	4	—	—	—	—	574	—	327	—	1·75	74	7·7	8	12
83	—	25	24	23	27	32	31	30	24	24	26	21	4	9	—	—	—	—	—	—	—	—	—	—	—	—	300	144	209	353	1·44	75	4	6	9
97	—	45	54	47	54	58	53	57	59	56	46	16	9	—	—	—	—	—	—	—	—	—	—	—	—	—	554	119	200	319	2·77	75	7·4	9	20
41	—	9	3	7	5	7	5	9	6	6	4	6	6	3	3	4	1	—	1	—	—	—	—	—	—	—	85 [4]	171	298	469	0·28	76	1·1	3	5
72	1	43	50	48	45	47	44	51	47	44	39	43	32	24	4	23	12	—	—	—	—	—	—	—	—	—	597	127	256	383	2·33	77	7·7	9	15
100	2	23	57	50	52	46	45	54	59	56	44	42	41	39	31	20	24	16	11	—	—	—	—	—	—	—	712	142	291	433	1·64	77	9·2	9	15
39	—	34	25	32	40	44	40	36	21	27	29	22	24	26	29	29	17	5	16	29	21	12	—	—	—	—	558	—	329	—	1·7	78	7·1	7	12
A	—	46	51	43	43	37	31	27	19	34	37	17	5	4	4	—	—	—	—	—	—	—	—	—	—	—	398	—	255	—	1·56	78	5·1	11	15
43	—	45	51	39	48	47	48	46	48	27	21	16	7	—	—	—	—	—	—	—	—	—	—	—	—	—	443	174	220	394	2·01	79	5·6	7	15
68*a*	—	41	40	47	42	38	44	49	44	43	45	41	27	12	—	—	—	—	—	—	—	—	—	—	—	—	513	144	215	359	2·39	79	6·5	7	15
88	1	42	46	47	45	46	49	46	41	52	46	47	41	42	—	—	—	—	—	—	—	—	—	—	—	—	591	125	211	336	2·8	79	7·5	8	16
99	1	42	51	49	49	51	53	52	52	47	38	13	20	18	—	—	—	—	—	—	—	—	—	—	—	—	536	118	210	328	2·55	79	6·8	7	16
58	—	35	57	50	52	51	54	49	38	47	38	26	8	15	16	16	1	—	—	—	—	—	—	—	—	—	553	127	250	377	2·21	80	6·9	8	16
68*e*	—	50	46	52	53	45	38	52	44	46	45	32	38	2	—	—	—	—	—	—	—	—	—	—	—	—	543	137	199	336	2·73	80	6·8	8	17
69	—	36	51	47	46	46	52	50	50	47	36	6	4	—	—	—	—	—	—	—	—	—	—	—	—	—	471	137	187	324	2·52	80	5·9	7	16
78	—	31	50	47	48	42	47	52	52	47	46	45	34	24	13	—	—	—	—	—	—	—	—	—	—	—	578	128	229	357	2·52	80	7·2	10	17
65	—	36	48	49	56	48	40	38	25	20	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	363	140	163	303	2·23	81	4·5	7	16
68*c*	2	41	47	52	52	47	48	48	55	43	41	23	23	16	13	—	—	—	—	—	—	—	—	—	—	—	551	139	228	367	2·42	81	6·8	7	14
68*f*	2	40	44	48	50	49	54	52	54	36	14	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	446	134	223	357	2	81	5·5	8	16
68*g*	2	42	47	50	54	53	44	49	51	50	46	39	26	10	2	—	—	—	—	—	—	—	—	—	—	—	565	142	239	381	2·36	81	7	8	16
73	4	37	55	52	47	45	48	46	44	40	29	17	9	2	12	5	2	—	—	—	—	—	—	—	—	—	494	130	260	390	1·9	81	6·1	7	15
77	—	33	51	52	52	54	63	61	57	51	52	31	36	11	6	—	—	—	—	—	—	—	—	—	—	—	610	136	240	376	2·54	81	7·5	8	16
68*b*	1	44	45	50	57	55	48	45	44	38	20	5	3	5	4	1	—	—	—	—	—	—	—	—	—	—	465	132	231	363	2·01	82	5·7	7	15
75	—	36	50	58	53	47	60	57	54	53	38	29	13	—	—	—	—	—	—	—	—	—	—	—	—	—	548	122	206	328	2·66	82	6·7	8	16
68*d*	—	42	48	45	50	43	45	43	46	32	31	17	41	37	16	—	—	—	—	—	—	—	—	—	—	—	536	138	230	368	2·33	83	6·5	7	15
Aver.	·5	34·8	41·3	41	42·7	41·2	40·6	40·2	38·3	35·1	30·2	21·4	17·4	12·6	7·8	5·5	3	1·2	1·2	1·2	·9	·5	—	—	—	—	462 [5]	136 [6]	225 [6]	361 [6]	1·94 [5]	77·7	6·6	11 [7]	20 [7]

[1] No. Ex. 18 suffered from abdominal excrescence.
[2] No. Ex. 22 suffered from abdominal constriction.
[3] No. 159 was abnormally short.
[4] No. 41 suffered like No. Ex. 22.
[5] Aver. for all 32 insects.
[6] Aver. for 24 insects only.
[7] Max. totals, not averages.

producer; when hatched out in order to free her hind-legs from the shell I asphyxiated her temporarily and accidentally cut off one foot, which was not regenerated. No. 41 developed a constriction like that of No. 22, and an external blood clot like that of No. 18. No. 100, which dropped the most eggs of any, was deformed by interpolated abdominal plates (see illustration), which evidently in no wise affected her productive powers. I had other insects similarly deformed and likewise good egg-bearers. No. 43 lived 30 days longer in the First Period than any others except the deformed No. 41. No. 65 abstained from food for 29 days before succumbing.

Egg-production.

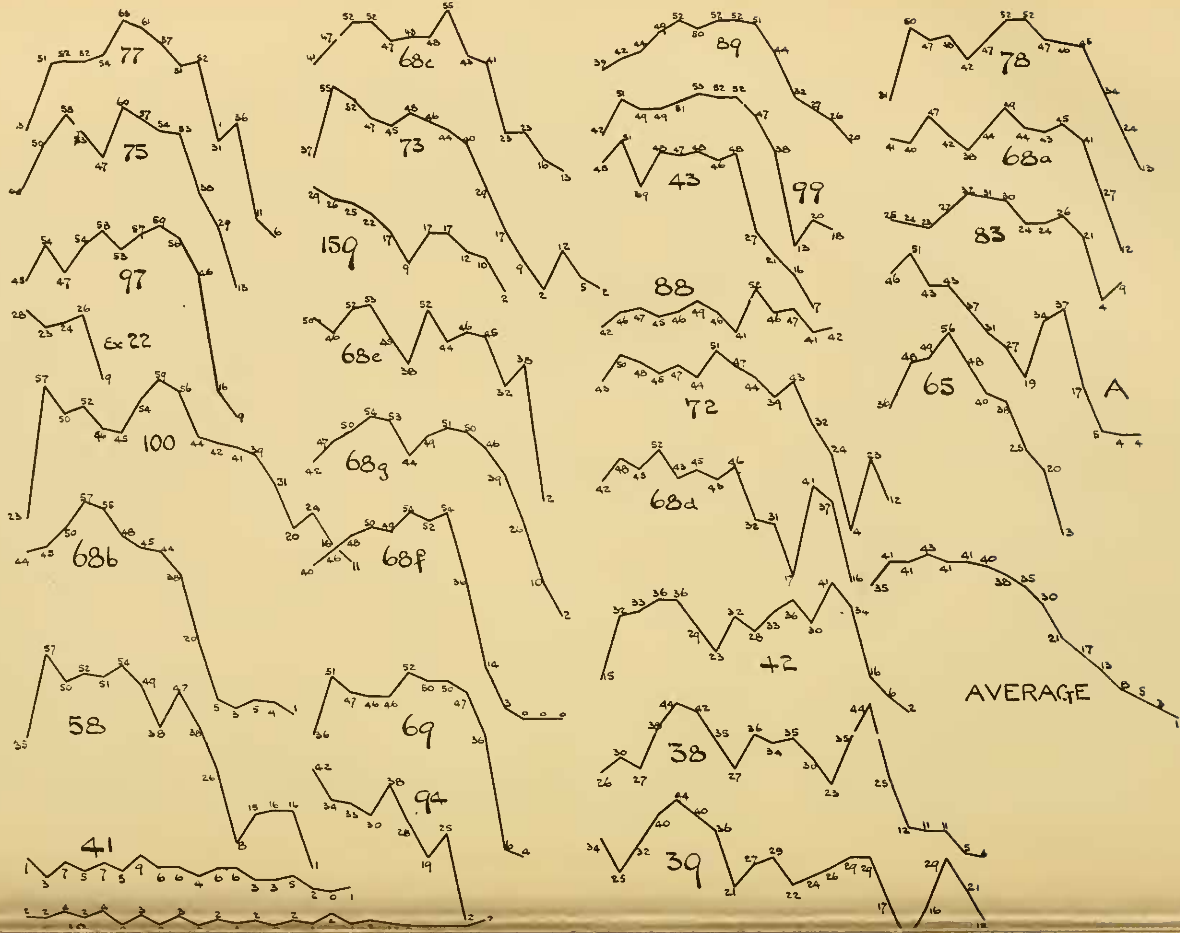
In Diagram I, the egg-production has been arranged in spells of 15 consecutive days each, ignoring the quantity dropped during the first spell of 15 days, during which the daily average is only ·5 eggs. The curves all seem to follow a general plan, viz. the greatest maximum per spell of 15 days occurs almost immediately after the commencement of egg-dropping, each succeeding maximum being lower than the last, and ending usually in a sudden drop with an occasional final rise.

There are, however, many deviations from this plan, some due probably to the individual peculiarities already referred to.

The average egg-production is 480 per insect, the highest total reached by any one insect, No. 100, amounting to 712 eggs.

The largest number of eggs laid in one day by one insect (No. A) was 11, which happened to be her start off with egg-dropping. Quantities of 10 and 9 are rare, but 8 and 7 eggs dropped in 24 hours by one insect are not rare, while 6 in a day are common enough. The highest total recorded for 3 consecutive days is 20 (by No. 97), equal to 6·6 per day, and for 15 consecutive days 63 (by No. 77), equal to 4·2 eggs per day. The average number of eggs dropped by all the insects under observation as per Table VI is 1·8 per day, but if we eliminate the imperfect or weak parents we get a more normal average of 2·2 per insect per day. The average record is affected in two ways: (1) by the interval elapsing between the last ecdysis and first egg-dropping, and (2) by the number of days lived after the last egg has been dropped. As regards the first interval, it is present

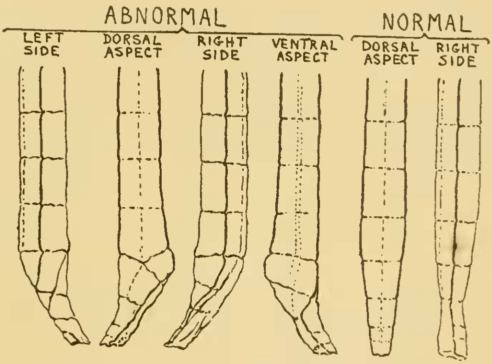
I. DIAGRAM TO ILLUSTRATE NUMBER OF EGGS PRODUCED IN 15-DAY SPELLS



in every case with a very even average of days, and so may be left out of consideration. As regards the later interval, there is considerable variation. Nos. 88 and 68*e* died in the midst of their egg-dropping, so there was no interval; No. 42 died 29 days after her last egg was dropped; No. 43 died 30 days after, while No. 68*f* died 45 days after dropping her last egg, and so on.

Excepting the case of No. 159, the abnormally short insect, there does not appear to be any actual correlation between the size of the insect and the quantity of eggs it can produce.

For instance, one insect 73 mm. long produced 595 eggs, and another 83 mm. long produced 536 eggs, or 59 eggs less, although it was 10 mm. longer. Four insects 79 mm.



long each produced respectively 443, 513, 536 and 591 eggs, and so on.

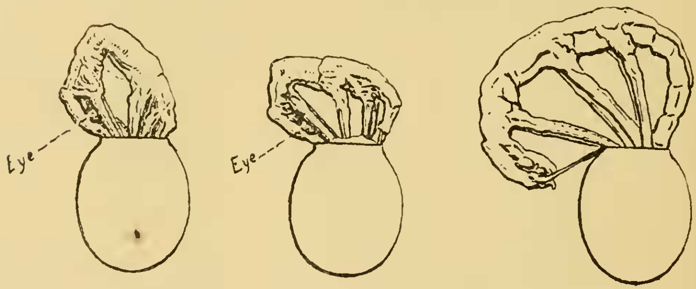
As regards the quantity of eggs produced per mm. length of the insect, two insects 75 mm. long each produced 4 and 7·4 eggs per mm. length respectively, while 6 insects 81 mm. long each produced 4·5, 5·5, 6·1, 6·8, 7 and 7·5 eggs per mm. length respectively. The average number of eggs produced per mm. length of the parent (exclusive of the original, which was not measured, and the abnormals, Nos. 18, 22, 41 and 159) is 6·5.

There does not seem to be any seasonal differences in the rise and fall of egg-production, which is quite independent of the time of year. Nor does the egg-production, in so far as quantity is concerned, depend absolutely on the number of days lived (Second Period); thus No. 78 lived 229 days and produced 578 eggs, while No. 38 lived 327 days and produced 574 eggs, or 4 eggs less for 98 more days of life.

Emergence from the Egg.

In outward form there is very little to distinguish the nymph when hatched out from the perfect imago after the sixth and last ecdysis except the size, although the segmentation of the thorax and of the antennae is not so clear in the newly emerged nymph as later on. The stick insect is therefore ametabolous or homomorphous. It is also menognathous, and from the time of hatching out until death it does not change its habits.

More nymphs hatch out during the night or in the early morning than in the daytime. When the nymph is



Nymphs hatching out, but which succumbed in the act, owing to the adherence of some of their appendages to the inside of the shell.

ready to emerge it forces up the cap and platform of the egg, which come away together, and then struggles out. I have not witnessed the pushing aside of the cap, nor am I sure that I have seen the first appearance of the head. The two hatchings out I witnessed, in which the heads were still bowed down when I first saw them, occupied under two minutes each. The heads may have been kept bowed down by a momentary adhesion of the antennae or fore-legs to the inside of the shell, as does occasionally happen, and if the nymph is unable to overcome this adhesion it succumbs. The adhesion of a hind-leg causes inconvenience for a time, as the nymph has then to drag the empty capsule about with it, and is hampered in its movements until the shell drops off. I have occasionally observed a nymph lose an entrapped appendage in its attempts to get free.

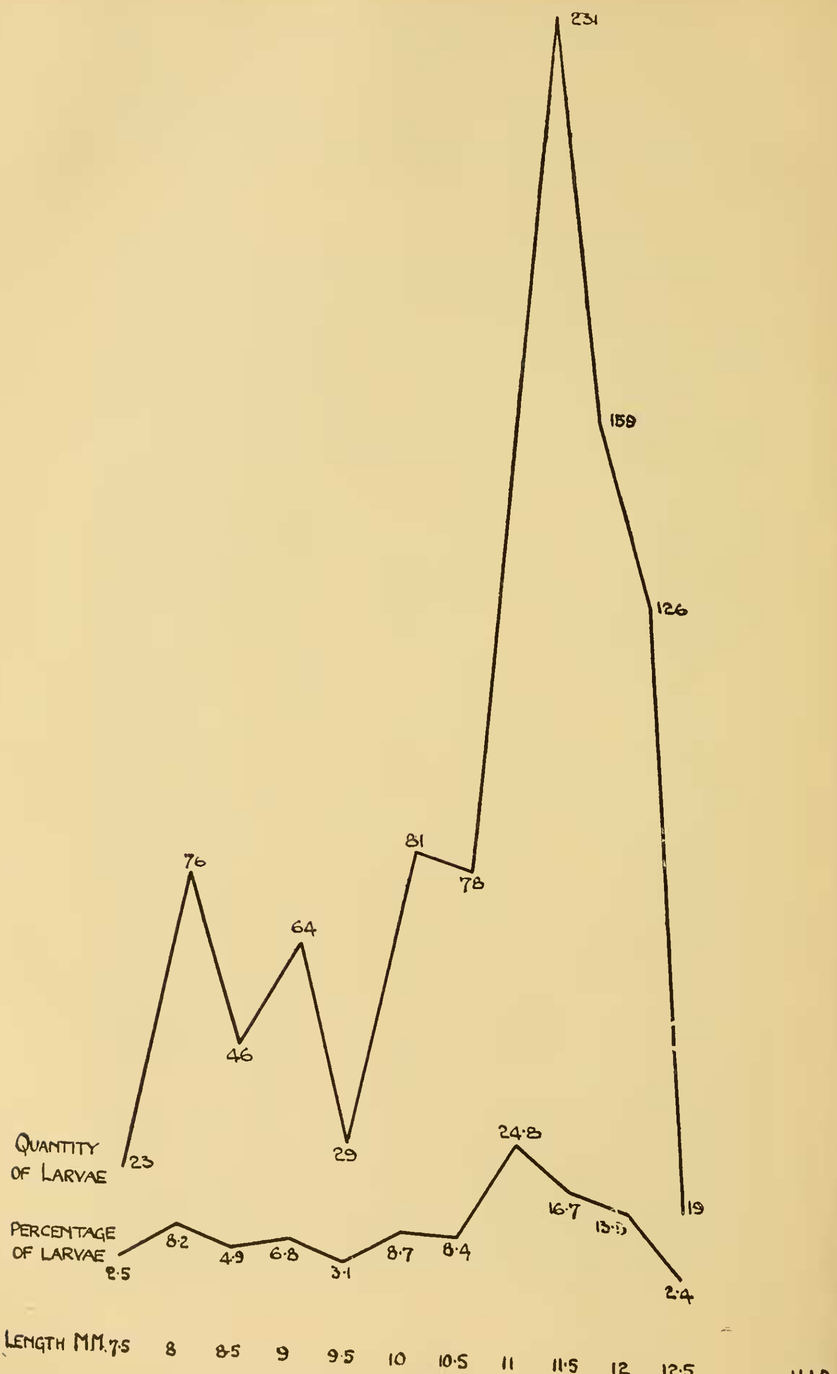
I think the normal emergence is by the pronotum coming out first, followed more or less simultaneously by the head and mesonotum, etc. That would correspond to the position of the nymph when about to slip out of its old skin at every ecdysis.

Increase in Length during the First Twenty-four Hours after Emerging from the Egg.

The growth of the nymphs from hatching out to the first ecdysis is perhaps not the least interesting part of a stick insect's life. As a preliminary to the investigation of this growth it was necessary to obtain accurate measurements of the size of the young immediately after emergence. To overcome the difficulties of accurately measuring living specimens the newly hatched young were, for several weeks, immediately killed and then immediately measured. The results of the measurements of 932 newly hatched young are shown graphically in Diagram II. The measurements were made to the nearest half-millimetre. The upper curve gives the details of the actual measurements, and the lower curve expresses these results in the form of percentages of the total number measured. The range in size of the newly hatched young is from 7·5 mm. to 12·5 mm., and the curve representing this range shows a more or less gradual rise with certain irregularities to 10·5 mm., a sharp maximum at 11 mm., and a less gradual fall to 12·5 mm. The average size of these 932 specimens is 10·5 mm., which is very close to the maximum of the graph. The results appear to indicate that a certain proportion of the nymphs are hatched out before the normal size is attained. Hence 25·5% of the hatchings, *i. e.* those under 10 mm. in length, might be expected to undergo one ecdysis more than those hatched out above that length; but this does not occur in so far as my experience goes, for such undersized nymphs as I have kept under observation went through the same number of ecdyses, *i. e.* six, before arriving at the same perfect state as those hatched 10 mm. long or over.

When newly hatched nymphs are placed on the upper side of a leaf they behave in various ways, viz. they rarely feign death, they remain stationary, or they walk to the edge of the leaf and attach themselves to the underside, or in their struggle to get away they run off in an excited manner with the abdomen curled over backwards (very

DIAGRAM TO ILLUSTRATE LENGTH OF 932 LARVAE ON HATCHING OUT II



different from their position in the egg), and tumble off the leaf; but generally they bend the head down, bringing the mouth close to the surface of the leaf as though in search of food. This search ultimately proved to be a search for moisture, which when found is imbibed with avidity. Occasionally the nymphs remain quietly imbibing water for as long as seven minutes, at other times much less, and at times only imbibing when their mouth was pushed into the moisture previously placed on the leaf.

It was in watching this imbibition that it became obvious to me that within a few hours of hatching out the nymphs rapidly increased their length by several millimetres per day, average 2·7 mm. in 24 hours.

Further examination showed that whether moisture was imbibed or not the increase was, with few exceptions, general. Of 164 newly hatched specimens put under observation, of which 47 were under 10 mm. long at emergence, all except 5 had increased to over 12–15 mm. long, or to an average length of 13·3 mm. at the end of 24 hours. This increase was probably due to the moisture taken up, for when not supplied with moisture the extension was slower. It cannot be due to food partaken, for during the first 24 hours hardly anything is eaten. Out of 206 specimens placed under observation only 56 ate at all, and the amount partaken was so infinitesimal, about a square millimetre or less, that it can be left out of consideration. The swift increase in length during the first 24 hours is the more extraordinary when we consider the results obtained in the life records of 26 specimens. From the date of hatching out till the first ecdysis, *i. e.* during an average period of 26 days, the average increase was only 10·1 mm. or under ·5 mm. per day. It is perhaps not correct to speak of the increase during the first 24 hours as a growth, but it should rather be spoken of as a physical extension or stretching out of the tissues after getting away from the confinement of the shell, which is largely aided by any moisture imbibed. The process is in all probability comparable with the universal phenomenon in Crustacea to stretch immediately after moulting.

The Growth to the First Ecdysis.

Subsequent to the extension which takes place, as already described, during the first 24 hours after hatching out, the nymphs commence to feed and to *grow* (Table

VII). This growth continues for 17 to 24 days (average about 21 days), during which time it increases in length at the rate of ·35 to ·7 mm. per day, or a total increase of 3 to 5·5 mm. This is the only period of its life during which it grows *without* shedding its outer skin, for the differences in length, if any, observed during the stadia between the successive ecdyses are infinitesimal. Towards the end of the 21 days or so the nymph has become very rotund, the abdominal segments bulge out very distinctly, it ceases to feed, and consequently to excrete, and remains quiescent. These are the outward evidences that ecdysis is about to take place.

The Ecdysis.

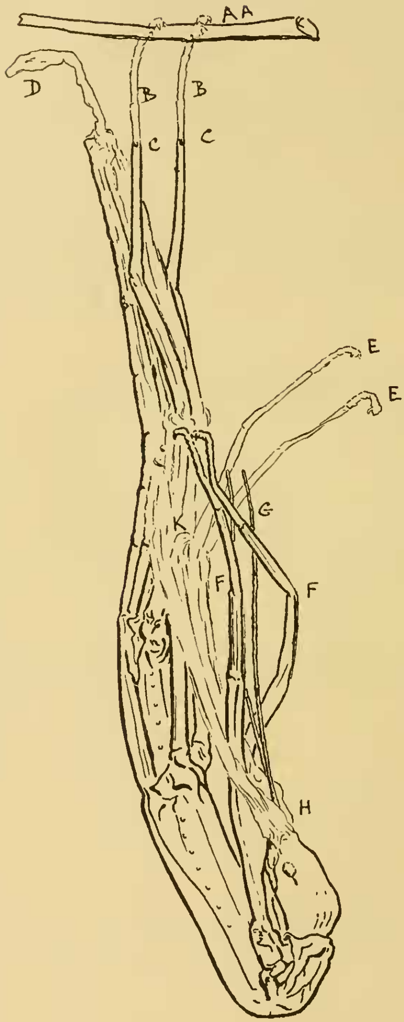
The fasting indulged in preparatory to slipping out of its old skin increases from 2 to 6 days, according to the number of moults it has or has not gone through. As per Table XIV, the average number of days' fast for the first moult is 2·7, and for the sixth moult 4·5.

As the moment approaches when the old skin is to be discarded the nymph gets into position by suspending itself from a twig or other object by its hind-legs, allowing the other two pairs to extend loosely more or less at right angles to its body and the antennae equally spread out. It takes 3 to 4 minutes to get into this position. Before it has quite settled to this it sways its body laterally in the way common to all the insects, but it ceases to do so when settled, and if there is any body movement during the ecdysis it somewhat resembles a faint longitudinal tremor, which becomes pronounced only when the slipping out is not progressing satisfactorily. There is no further lateral movement nor any turning nor twisting. The preliminary common lateral movement may do something towards easing the skin preparatory to discarding the old skin, but it is quite a distinct movement from the rare one observed in the actual ecdysis.

After hanging for a very few minutes in the position indicated the nymph attaches its fore-legs to the femurs of the middle-legs, or occasionally to the twig or leaf from which it is suspended, if close enough. This brings the head to point upwards instead of downwards and more than parallel with the body, so that the head is at an acute angle with the pronotum and the pronotum is at right angles to the mesonotum, while the metanotum remains

Table VII.—Consumption of Food (F) in square mm. and Lineal Growth (G) in mm. per day from Hatching out up to and inclusive of the First Ecdysis.

Series No.	187		188		190		191		192		193		194		195	
Hatched Days	F	G	F	G	F	G	F	G	F	G	F	G	F	G	F	G
	—	11·5	—	11·5	—	12	—	11	—	11	—	11	—	11·5	—	12
1	2	11·5	2	12	0	12	0	12	0	12 ?	0	11	0	11·5	0	12
2	0	12	2	13	3	12	0	12	0	11·5	0	11·5	1	11·5	1	12
3	2	12	3	13	3	12	0	12	0	11·5	0	11·5	0	11·5	0	12
4	3	13	6	13	0	12	0	12	9	12	9	11·5	7	11·5	0	12
5	12	13	10	13	0	12·5	0	13	5	12	8	12	2	11·5	4	12
6	5	13	8	14	9	13	9	13	7	12·5	12	12	4	11·5	8	12
7	9	14	9	14	5	13	9	14	11	13·5	9	12·5	8	12	10	12
8	13	14·5	15	14·5	5	13	18	14·5	18	14	9	13	5	12	5	12·5
9	13	15	9	15	7	13	13	15	14	14	8	13·5	3	12	7	13
10	15	15	8	15·5	12	14	8	15	6	14·5	9	14	6	12·5	10	14
11	8	15	25	16	9	14	20	16	20	15	9	14	7	13	7	14
12	0	15	16	16	6	14	12	16	15	15	11	14·5	10	14	8	14
13	27	15	0	16	11	14·5	18	16	14	15	4	15	11	14	12	14·5
14	0	15	18	16·5	21	14·5	10	16	19	15	10	15	7	14·5	13	15
15	11	15·5	0	16·5	18	15	9	16·5	15	15·5	9	15	14	15	12	15
16	0	16	0	16·5	20	15	6	16·5	0	15·5	6	15	10	15	9	15
17	0	16	0 Ec	22·5	17	15·5	0	16·5	0	15·5	0	15	3	15	5	15
18	0	16			14	16	0	16·5	0 Ec	21	0 Ec	19·5	0	15·5	0	15
19	0	16			10	16	0 Ec	20·5					0	15·5	0	15
20	0 Ec	20·5			0	16							0	15·5	0 Ec	19
21					6	16							0 Ec	20		
22					0 Ec	21										
F Total	120		131		176		132		153		113		98		111	
F per mm. G	13·3		11·9		19·5		13·9		17		13·3		11·5		15·8	
F per day	6		7·7		8		7		8·5		6·3		4·7		5·5	
G up to 1st Ec		4·5		5		4		5·5		4·5		4		4		3
G at 1st Ec		4·5		6		5		4		5·5		4·5		4·5		4
G per day		·5		·7		·41		·5		·56		·47		·4		·35



C. morosus in the act of moulting. AA. Claws of hind pair of legs by which it is suspended. BB. Empty skins of these legs. CC. Distance to which so far the legs have receded in the skins. D. Empty apical abdominal segment falling backwards. EE. Empty skins of middle pair of legs. FF. First pair of legs not yet freed. G. Antennae not yet freed. H. Skin coming off snout. K. The shedded skin.

more or less in a straight line with the abdomen. The split skin can then almost immediately be seen as it were moving across the sides of the head, and at the same time the apical abdominal segment can be seen to have slipped down from the inside of the old and contracting integument, which commences to fall over backwards. There is now a considerable bend at the thoracic-abdominal joint as the body slowly glides down out of the skin, and the antennae are forced forward by the pressure of the skin. Then the middle-legs get loose and begin to spread sideways, quickly followed by the hind pair. Immediately afterwards the antennae and first pair of legs get free, the latter spreading out like the others and the antennae now no longer holding up the head, this moves slowly backwards and downwards in a line with the whole body into its normal position.

The nymph is now in the same outstretched pendant attitude it assumed when the ecdysis started, except that it hangs by the last two abdominal segments, kept there by the contraction of the discarded exoskeleton, instead of by its hind-legs, the old skin being still suspended by its now empty leg skins.

As the slough is left by the body it contracts and we have thus two motions, the contracting old skin moving upwards and the body moving downwards. The latter motion is quite involuntary on the part of the nymph or insect, being due to the action of gravity after the skin over the pro- and mesonota supporting the body has split, which lets the body slide down and out.

If at the beginning of the moult the nymph falls from its support it cannot get free from the old skin, and succumbs in spite of its wriggling while on the ground; but if the ecdysis is well advanced before such a fall the nymph will generally get free.

The time taken to get to the clearance point is about 20 to 45 minutes or a little more. The nymph remains almost motionless in this position for about 30 or 40 minutes more, when it will make a sudden convulsive movement, bend its body forward, bring up its head and reverse its position, now hanging by its first pair of legs, head upwards, quite clear of the slough. The whole procedure, now complete, occupies from 55 to 70 minutes from start to finish.

In this, the final position, the nymph or insect remains quiescent from a few minutes to several hours, after which it commences to eat up the old skin close to which it has attached itself. This meal is an almost invariable proceeding, unless through some accident the slough has fallen to the ground or the nymph has been disturbed in some way. The skin shrivels considerably, so that the head portion is not very low down, and it is here that the nymph begins its repast, *not* biting pieces off, but drawing in the skin by means of the palpi. When it has devoured the skin of all but one hind-leg it looks for this, generally detached in the course of the feed, eats it up also, and then searches the twig for more. If the skin has fallen the nymph or insect will look for it where it should be, and occasionally hours afterwards it may devour it when it finds it. If otherwise disturbed at this meal it may eat part only or none at all. The proportion of uneaten sloughs is greater when there are a large number of nymphs or insects in a jar than when a nymph has a jar to itself, for they disturb one another very considerably. I once saw a nymph start to eat up a newly discarded skin before its proper owner was ready to begin on it. Occasionally, too, in the course of the shedding the nymph is disturbed by another crawling over it, whereupon it gives its body a jerk which does not always get rid of the troubler. Preparatory to the change the nymph is not very particular as to what it attaches itself to, and will even adhere to another nymph, and as this species has a common habit of hanging five or six close together in the day-time, like a bunch of asparagus, the quiet progress of the moult does not in any way cause a disturbance, and proceeds as in the ordinary course.*

On one occasion I observed a clot of green liquid develop at the proto-mesonotum joint similar to that mentioned on p. 357. It was about 1·5 mm. in diameter, did not seem to inconvenience the nymph at all, and gradually disappeared, apparently by absorption. This clot appeared after the discarded skin had passed clear of the head.

After the ecdysis the body is much attenuated and generally lighter and brighter in colour; in the course of 3 to 4 days it has filled out again, and if the full number of moults has not been passed the swelling slowly recommences until the next ecdysis occurs.

* With the Walking-Stick, *Diapheromera femorata*, Say, H. H. P. and H. C. Severin observed a peristaltic-like movement in the course of the moult (*loc. cit.*, 1911, p. 313).

TABLE VIII.—INCREASE IN LENGTH OF NYMPHS AT EVERY SUCCESSIVE ECDYSIS.

Specimen's Number.	Length on	From Hatching to	Increase up to	Increase at	From First Ecd. to	Increase at	From Second Ecd. to	Increase at	From Third Ecd. to	Increase at	From Fourth Ecd. to	Increase at	From Fifth Ecd. to	Increase at
	Hatching.	First Ecd.			Second Ecd.		Third Ecd.		Fourth Ecd.		Fifth Ecd.		Sixth Ecd.	
	Mm.	Days.	Mm.	Mm.	Days.	Mm.	Days.	Mm.	Days.	Mm.	Days.	Mm.	Days.	Mm.
98	9	24	6·5	5·5	17	7	19	9	20	12	19	15	24	19
99	11	21	5	5	17	8	19	10	19	11	19	13	23	16
101	10	21	6	5	17	9	19	8	19	12	18	18	23	15
68*a*	12	29	5	4	21	9	23	8	22	11	22	16	27	14
68*b*	12	25	4	5	21	8	22	9	20	13	20	14	24	17
68*c*	11·5	28	5·5	4	22	7·5	21	9·5	20	11	21	13	27	19
68*d*	12	28	5	5	23	7	22	9	19	12	19	15	27	18
68*e*	12	28	4	4	18	8	23	9	21	13	20	14	27	16
68*f*	11·5	23	4·5	5·5	21	6·5	22	10	22	11	20	15	26	17
68*g*	11·5	29	5	4	22	7·5	21	10	21	11	20	13	29	19
69	12	29	4·5	5	21	7·5	17	9	22	11	20	16	28	15
72	11	27	5	5	19	8	16	9	19	10	20	14	26	15
73	11	26	5	5	19	9	19	7·5	17	11·5	22	15	27	17
75	12	25	4·5	5·5	18	7	15	10	19	12	21	12	24	19
77	12	27	4·5	5·5	21	7	18	10	19	13	27	14	24	15
78	11	28	5	5	18	7·5	20	9·5	18	12	19	13	25	17
83	11	28	5	4	24	6	20	8	24	11	21	13	27	17
84	9	24	6	6	18	7	17	9	19	11	23	14	26	15
88	12	25	4	6	17	8	16	7·5	19	13·5	24	13	24	15
89	8·5	34	6·5	2	16	7	19	10	21	11	20	13	23	16
90	8·25	22	7·75	5	16	8	18	10	26	11	22	15	26	15
91	8·25	22	7·75	5	17	7	16	10	22	12	20	14	27	20
92	7·25	24	6·75	4	19	7	19	9	24	12	19	13	25	17
94	8	28	7	3	20	6	17	8	23	10	20	14	25	14
95	10·5	25	5·5	3·5	19	8·5	21	9	15	11	19	14	24	17
97	8·5	22	6·5	5	17	6	19	10	20	11	18	14	23	14
Max.	12	34	7·75	6	24	9	23	10	26	13·5	27	18	29	20
Min.	7·25	21	4	2	16	6	15	7·5	15	10	18	12	23	14
Aver.	10·5	25·8	5·4	4·7	19·1	7·5	19·1	9·1	20·4	11·5	20·4	14·1	25·4	16·5

Table IX.—Length of Nymphs at every successive Ecdysis.

Specimen's Number.	Length on Hatching.	From Hatching to First Ecd.	Length at First Ecd.	Length after First Ecd.	From Hatching to Second Ecd.	Length after Second Ecd.	From Hatching to Third Ecd.	Length after Third Ecd.	From Hatching to Fourth Ecd.	Length after Fourth Ecd.	From Ha ching to Fifth Ecd.	Length after Fifth Ecd.	From Hatching to Sixth Ecd.	Length after Sixth Ecd.
	Mm.	Days.	Mm.	Mm.	Days.	Mm.	Days.	Mm.	Days.	Mm.	Days.	Mm.	Days.	Mm.
98	9	24	15·5	21	41	28	60	37	80	49	99	64	123	83
99	11	21	16	21	38	29	57	39	76	50	95	63	118	79
101	10	21	16	21	38	30	57	38	76	50	94	68	117	83
68*a*	12	29	17	21	50	30	73	38	95	49	117	65	144	79
68*b*	12	25	16	21	46	29	68	38	88	51	108	65	132	82
68*c*	11·5	28	17	21	50	28·5	71	38	91	49	112	62	139	81
68*d*	12	28	17	22	51	29	73	38	92	50	111	65	138	83
68*e*	12	28	16	20	46	28	69	37	90	50	110	64	137	80
68*f*	11·5	23	16	21·5	44	28	66	38	88	49	108	64	134	81
68*g*	11·5	29	16·5	20·5	51	28	72	38	93	49	113	62	142	81
69	12	29	16·5	21·5	50	29	67	38	89	49	109	65	137	80
72	11	27	16	21	46	29	62	38	81	48	101	62	127	77
73	11	26	16	21	45	30	64	37·5	81	49	103	64	130	81
75	12	25	16·5	22	43	29	58	39	77	51	98	63	122	82
77	12	27	16·5	22	48	29	66	39	85	52	112	66	136	81
78	11	28	16	21	46	28·5	66	38	84	50	103	63	128	80
83	11	28	16	20	52	26	72	34	96	45	117	58	144	75
84	9	24	15	21	42	28	59	37	78	48	101	62	127	79
88	12	25	16	22	42	30	58	37·5	77	51	101	64	125	79
89	8·5	34	14	16	50	23	69	33	90	44	110	57	133	73
90	8·25	22	16	21	38	29	56	39	82	50	104	65	130	80
91	8·25	22	16	21	39	28	55	38	77	50	97	64	124	84
92	7·25	24	14	18	43	25	62	34	86	46	105	59	130	76
94	8	28	15	18	48	24	65	32	88	42	108	56	133	70
95	10·5	25	16	19·5	44	28	65	37	80	48	99	62	123	79
97	8·5	22	15	20	39	26	58	36	78	47	96	61	119	75
Max.	12	34	17	22	52	30	73	39	96	52	117	68	144	84
Min.	7·25	21	14	16	38	23	55	32	76	42	94	56	117	70
Aver.	10·5	25·8	16	20·6	45	28	64	37	84·5	48·7	105	62·8	130	79

There are six ecdyses in all, and none after full growth is attained. With regard to the number of moults MacBride and Jackson (*op. cit.* p. 109) state they had observed seven moults, and that Meissner was mistaken as to the actual number of ecdyses. My own observations, however, based on two separate series of specimens, proved definitely that six ecdyses actually occurred. The discrepancy in the number of ecdyses may possibly be due to the insect producing one or more races which differ as to the number of ecdyses.

With regard to the number of ecdyses, it is interesting to note that Sinéty ("Recherches sur la biologie et l'anatomie des Phasmes," 1901, p. 18) records five ecdyses in the case of one individual of *C.* (*Dixippus*) *morosus* and six ecdyses in another.

Growths after the First 24 Hours from Hatching Out up to and including the Last Ecdysis.

The growth, as ascertained by measurements taken on hatching out and at each successive ecdysis, of which there are six in all, is shown in the two summarised Tables Nos. VIII and IX. There is a consistent increase in the rate of growth from first to last, although this does not appear to be the case in the growth from hatching out to the first ecdysis. If, however, for the length on emergence from the egg averaging 10·5 mm., we take the corrected hatching-out length to be 13·3 mm. as already explained, the growth to the first ecdysis will be 2·6 mm. instead of 5·4 mm., and the average increase will then be as follows—

Table X.—Corrected Average Increase.

To I Ec.	At I Ec.	At II Ec.	At III Ec.	At IV. Ec.	At V Ec.	At VI Ec.
2·6	4·7	7·5	9·1	11·5	14·1	16·5 mm. per Ec.

Similarly the diurnal rate of growth is an augmenting one with each successive ecdysis except the last one, thus—

Table XI.—Diurnal Rate of Growth.

To I Ec.	To II Ec.	To III Ec.	To IV Ec.	To V Ec.	To VI Ec.
0·28	0·39	0·48	0·56	0·69	0·65 mm. growth per day

Generally speaking, if at any time it is desired to ascertain the stadium of a stick insect, one has only to measure it, thus: a stick insect measuring, say, 33 mm. will have passed its second moult, and so on.

The Insect's Length.

The length of the individual full-grown insects varies very considerably, as the following Table of the summary of the measurements of 354 mature insects shows. These insects were the whole of the surviving progeny of one parent, measured as soon as they themselves began to drop eggs.

Table XII.—Lengths of Full-grown Insects—Bred from "Original" Female.

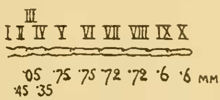
Specimens' Numbers.	Dates of the Dropping of the Eggs from which these Insects hatched out.	Quantity of Specimens Measured.	Length in mm.		
			Max.	Min.	Aver.
1–5	19 June–19 July	53	81·5	74	77
6–11	20 July–7 Sept.	61	81	72	77·7
12–15	8 Sept.–3 Nov.	54	83	77	79·4
16–17	4 Nov.–25 Dec.	57	86	75	82
18–20	26 Dec.–16 Mar.	61	86	76	82·2
21–23	17 Mar.–13 May	68	84	75	81·8
		354	86	72	80·1

The range in the length of the adult insects is therefore 14 mm. from a minimum of 72 mm. to a maximum of 86 mm. I have no other records which exceed the above maximum of 86 mm., but I have two records which do not come up to the above minimum of 72 mm., viz. No. 42, an almost black insect and a very good egg-producer, which measured only 69 mm., and No. 159, a runt, which both ate and produced little and was only 62 mm. in length.

The Growth of the Antennae.

In connection with the body growth, as illustrated by the successive ecdyses, it is interesting to note the growth of the antennae. When hatched out the nymph's antennae consist of ten segments, the joints of which can nearly all be distinguished by the naked eye. Under the microscope on segments IV, V and VI, counting from the base, are to be seen indications of further segmentation, which develops with successive ecdyses. The three basal segments increase in size, but do not subdivide. Segment IV gets broken up into as many as 10 very distinct divisions by the time the last ecdysis has taken place. Segment V breaks up into 4 to 7 divisions; segments VI and VII break up into 4 to 6 divisions, rarely into 7 divisions; segment VIII into 4 divisions and occasionally 6 divisions; segment IX into 3 divisions; segment X into 2 or rarely into 3 divisions. In fact, the nearer we get to the apex the less the number of sub-segments to the original or pre-ecdysical segments.

At the same time the original segments increase in length, but not all to the same extent. Their increase is shown in the following table. The number of segments on the right and left antennae of one and the same insect are not always the same.

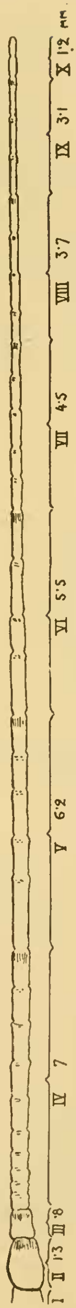


Antennae on emergence × 5.

Coincident with the growth of the antennae the body (including head, thorax and abdomen) increases from 10 or 11 mm. to 80 mm. (Tables III and IV), or seven- or eight-fold. But if we accept a length of 13·3 mm. as the starting-point for growth after hatching out, then the increase of the whole body in length is six-fold, the growth

TABLE XIII.—GROWTH OF THE ANTENNAE.

Segment No. (from Base).	Length.		Rate of Growth.
	At Hatching.	After Sixth Ecdysis.	
I	—	—	—
II	·45	1·3	3 fold
III	·05	·8	16 ,,
IV	·35	7	20 ,,
V	·75	6·2	8·3 ,,
VI	·75	5·5	7·5 ,,
VII	·72	4·5	6 ,,
VIII	·72	3·7	5 ,,
IX	·6	3·1	5 ,,
X	·6	1·2	2 ,,
Total	5	33	6·6 fold



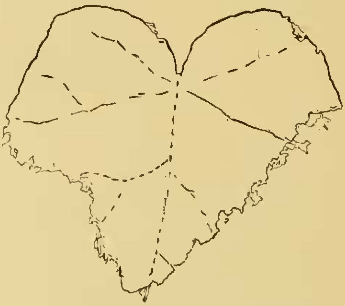
Antennae after the last moult × 5.

of the antennae being practically the same as that of the rest of body.

Food Consumption.

It follows from the form of the feeding organs that the stick insects are edge feeders and not surface feeders, cutting off strip after strip of leaf and swallowing them down whole. When decay approaches they often have difficulty in making the final bite to release the strip, and then when they move the head backwards the whole strip reappears out of their mouth still attached to the leaf. When young the bite is clean; as age increases it becomes jagged and rough (see illustration).

A partly consumed leaf showing the clean-cut edges when the nymph or insect is in good health.



A partly consumed leaf, showing the jagged edges where the insect has been feeding when decay has already set in.

They show considerable difference in their choice of food. Sometimes they will eat of one leaf, daily returning to it till it is all or nearly wholly consumed, and in the meanwhile not touch any other; at other times they will eat a small portion out of several leaves. Occasionally they will continue eating a sere or flaccid leaf instead of consuming an adjacent fresh one. They are irregular feeders, eating much one day and little the next, and so on, but always more immediately after a moult than later on in the same stadium. Except at the moults, already referred to, they feed daily and only abstain through accident, sickness or the approach of decay. Their feeding generally takes place in the evening and in the morning.

I understand that most people who keep stick insects provide them with privet to feed on. The late Mr. Meade-Waldo informed me that " in greenhouses where they have been raised from the eggs they havestarted feedingon privet, and when by some accident they get separated from it they feed equally well on *Coleus*, *Fuchsia* or many other plants, at least that is my experience." My objection to privet is that, in my garden at least, if the weather is at all severe the leaves get nipped by the frost and drop off before new ones appear; in other words, they are not sufficiently persistent for food-observation purposes. Ivy is a good substitute.* The smoke with us blackens the leaves, which, except in late spring when the new leaves have not yet attracted the smuts, necessitates their being washed before being given as food to the insects. All the observations with regard to food consumption were made with ivy leaves as food. In connection with these observations it may be remarked that towards the middle of May there is usually a little difficulty in getting suitable ivy leaves, for the old leaves are then almost past service and the young ones are still too flabby, either continuing to grow after being cut, or shrivelling up quickly and so tending to vitiate the correctness of the records. As the calculations are based on the superficial area and not on the cubical contents of the portion of the leaf consumed, it was essential to supply leaves of uniform thickness in so far as this could be done.

In order to ascertain the amount of food consumed, outlines of the leaves were drawn by placing the leaves on sheets ruled in mm. squares and running a pencil round

* As regards some Stick Insects reared in India (paper by Ramakrishna Aiyer in Jour. Bombay Nat. Hist. Soc., xxii, pp. 641–3), to which my attention has been kindly called by F. H. Graveley of the Indian Museum, Calcutta), it seems that many food plants were tried, and eventually, after many deaths had occurred, some insects took to *Hibiscus esculentus* and were successfully reared on it. The name of the insect is not given. Rowland Turner informs me that in Queensland the stick insects ate gum leaves (*Eucalyptus*); these were large Phasmids (*Cyphocrania goliath*); smaller species he found devouring guava. Otto Meissner gives a list of plants, with the leaves of which he has supplied stick insects (and nymphs), and has tabulated the plants according to the preference shown for them; he found radish leaves and hazel nut leaves most in demand (" Biol. Beobach. a. d. Ind. Strohheuschrecke Dixippus morosus," Z. f. wiss. Insektenbiologie, v, 1909, pp. 20 and 56). Schleip fed his nymphs on rose leaves and his imagines on ivy (*op. cit.*, p. 48).

TABLE XIV.—FOOD CONSUMPTION BY, AND GROWTH OF, NYMPHS DURING THE FIRST PERIOD, *i.e.* FROM HATCHING OUT UP TO AND INCLUDING THE SIXTH (LAST) ECDYSIS.

	No. of Days' Fast previous to Ecd.	Lineal Increase in mm. since previous Ecd.	Food Consumption in sq. mm. since previous Ecd.	Food Consumption in sq. mm. per lineal mm. Increase.	No. of Days since previous Ecd.	Food Consumption per Day since previous Ecd.	No. of Days' Fast previous to Ecd.	Lineal Increase in mm. since previous Ecd.	Food Consumption in sq. mm. since previous Ecd.	Food Consumption in sq. mm. per lineal mm. Increase.	No. of Days since previous Ecd.	Food Consumption per Day since previous Ecd.
	No. 181.						No. 183.					
I	2	10	142	14·2	18	8	2	10	167	16·7	21	8
II	5	7·5	397	52·9	23	17	3	9	274	30·4	14	20
III	3	9·5	579	61	17	34	3	8·5	547	64	15	36
IV	3	12	1,449	121	17	85	2	12	1,219	102	17	72
V	4	12	2,831	236	19	149	4	15·5	2,589	158	18	144
VI	5	17	6,485	381	22	295	4	14·5	5,711	394	23	248
Total	22	68	11,883	175	116	102	18	69·5	10,507	153	108	97
	No. 188.						No. 190.					
I	3	11	131	11·9	17	8	1	9	176	19·5	22	8
II	4	7·5	267	36	14	19	2	8	282	35·2	15	19
III	4	9	709	79	17	42	3	8	756	94	16	47
IV	5	11	1,382	122	17	81	3	13	1,433	110	16	90
V	4	14	2,931	209	18	163	4	14·5	2,399	165	19	126
VI	5	18	8,164	453	22	371	5	14·5	6,056	418	21	288
Total	25	70·5	13,584	193	105	129	18	67	11,102	166	109	102
	No. 193.						No. 194.					
I	2	8·5	113	13·3	18	6	4	8·5	98	11·5	21	5
II	2	7·5	212	28·3	14	15	3	8	263	32·8	16	16
III	3	9	460	51	17	27	3	8	605	76	17	36
IV	4	12·5	1,361	109	16	85	4	13	1,413	109	19	74
V	4	14	2,578	184	19	136	3	14	2,652	189	20	133
VI	4	18·5	6,853	370	21	326	5	16	6,474	405	24	270
Total	19	70	11,577	165	105	110	22	67·5	11,505	168	117	98

	No. of Days' Fast previous to Ecd.	Lineal Increase in mm. since previous Ecd.	Food Consumption in sq. mm. since previous Ecd.	Food Consumption in sq. mm. per lineal mm. Increase.	No. of Days' since previous Ecd.	Food Consumption per Day since previous Ecd.	No. of Days' Fast previous to Ecd.	Lineal Increase in mm. since previous Ecd.	Food Consumption in sq. mm. since previous Ecd.	Food Consumption in sq. mm. per lineal mm. Increase.	No. of Days since previous Ecd.	Food Consumption per Day since previous Ecd.
	No. 184.						No. 187.					
I	3	10	89	8·9	17	5	4	9	120	13·3	20	6
II	4	7	280	40	16	17	3	7·5	286	38·1	14	20
III	4	9	553	66	16	34	3	9	590	65	15	39
IV	3	12	1,165	97	16	73	3	13	1,275	98	18	71
V	4	16	3,452	215	18	192	4	12	2,361	197	17	139
VI	5	14	6,852	489	24	285	4	16	6,564	410	21	313
Total	23	68	12,391	182	107	116	21	66·5	11,196	168	105	107
	No. 191.						No. 192.					
I	3	9·5	132	13·9	19	7	3	9	153	17	18	9
II	3	7·5	333	44·4	16	21	3	7·5	241	32·1	16	15
III	4	9	452	50	15	30	3	9	569	63	15	38
IV	3	12	1,561	130	15	104	5	11·5	1,230	107	16	77
V	4	14	2,521	180	18	140	3	14	2,092	150	19	110
VI	5	16	6,444	403	21	307	4	19	6,130	323	22	279
Total	22	68	11,443	168	104	110	21	70	10,415	149	106	98
	No. 195.						Averages.					
I	2	7	111	15·8	20	5·5	2·6	9·2	130	14·2	19	7
II	3	7·5	235	31·3	17	14	3·2	7·7	279	36·5	16	17·5
III	4	8·5	550	65	16	34	3·4	8·7	579	66	16	36
IV	4	11	1,084	98	16	68	3·5	12·1	1,121	110	17	79·6
V	4	14	2,457	175	20	123	3·8	14·1	2,611	186	19	140
VI	5	17	6,185	364	23	269	4·6	16·4	6,538	398	22	295
Total	22	65	10,622	163	112	95	21	68·2	11,475	168	109	106

their edges; these leaves were then put at the disposal of the insect. At the end of twenty-four hours (the next morning) the leaves were fitted into their respective outlines on the sheets, and the portion missing, *i. e.* consumed, was outlined and the leaves replaced with the insect. The number of square mm. in the missing portion was then counted, and recorded day by day as the amount of leaf consumed.

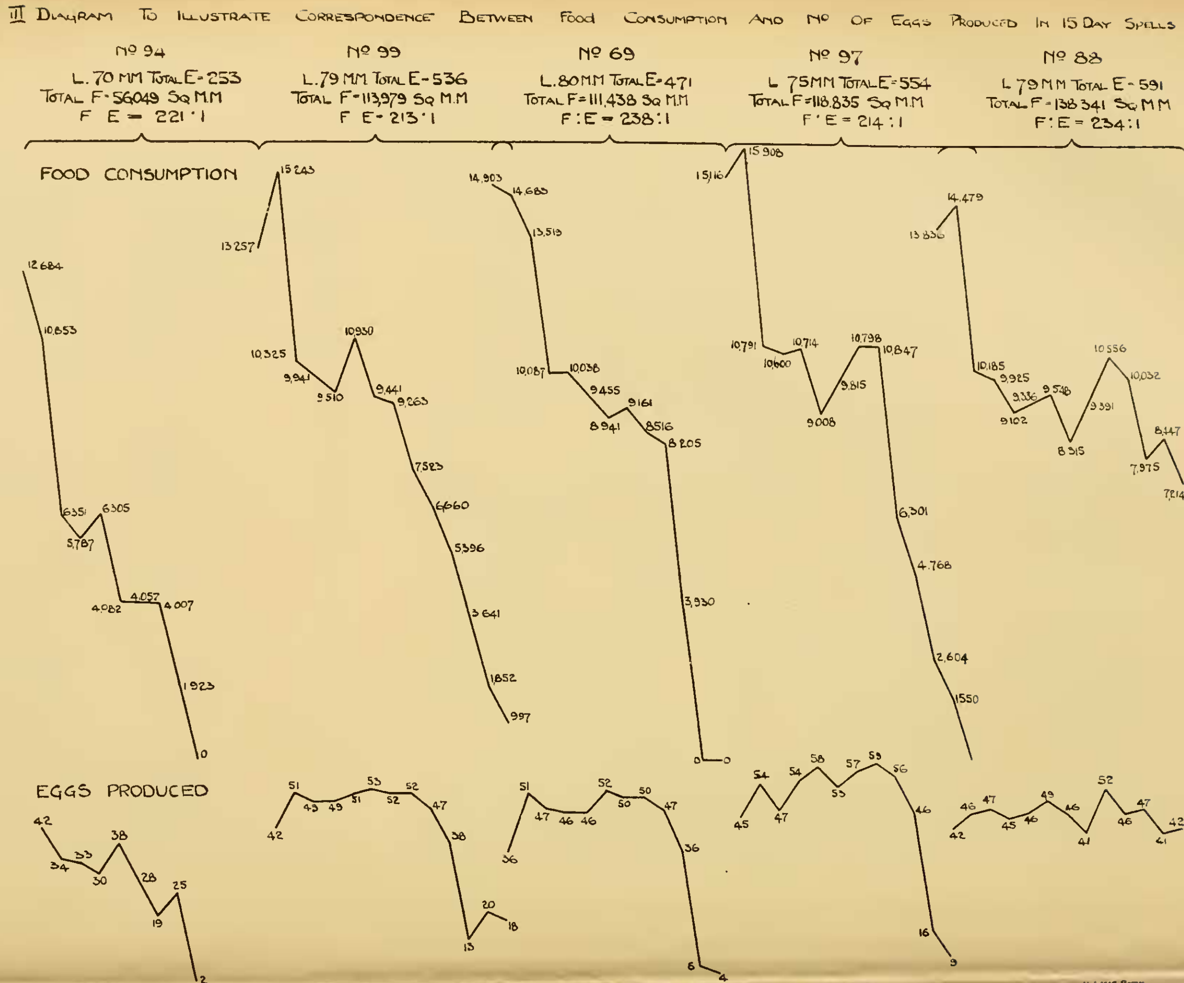
As shown in Table XIV, the food consumption doubles with each successive stadium and not merely in actual quantity, for the quantity consumed increases per mm. length of the insect at the same time, thus: in the 1st stadium the consumption per mm. length of the insect is 7 sq. mm., in the 2nd 17·5 sq. mm, in the 3rd 36, in the 4th 79·6, in the 5th 140, in the 6th 295, and after the 6th 597 (see Table XV), and these figures are as near as possible 9, 18, 36, 72, 144, 288, and 576, respectively.

For the two or three weeks immediately following the last ecdysis the insects eat enormously (as can be seen from Diagram III), afterwards, generally speaking, they gradually eat less and less. As the same diagram indicates, there is considerable correspondence between the food consumed and the eggs produced.

As with the egg-dropping, so too with the food consumption, the size of the insect appears to have nothing to do with the results, and according to Table XV a shorter insect may eat more than a longer one.

Table XV.—Food Consumption by Full-Grown Insects.

Specimen's Number.	Length of Insect. mm.	Total sq. mm. of Leaf consumed.	No. of Days lived (IInd Period).	Total No. of Eggs dropped.	Averages.			
					No. of Eggs dropped per Day.	Sq. mm. of Leaf consumed per Day.	Sq. mm. of Leaf consumed per mm. Length of Insect.	Sq. mm. of Leaf consumed per Egg dropped.
69	80	111,438	187	471	2·52	596	1392	238
88	79	138,341	211	591	2·8	656	1751	234
97	75	118,835	200	554	2·77	594	1584	214
99	79	113,979	210	536	2·55	543	1443	213
94	70	56,049	142	253	1·78	395	800	221
Aver.	78·2	120,648	202	538	2·66	597	1541	225


III Diagram To Illustrate Correspondence Between Food Consumption And No of Eggs Produced In 15 Day Spells
Nº 94
L. 70 MM Total E-253
Total F-56049 Sq M.M
F E = 221·1
Nº 99
L. 79 MM Total E-536
Total F-113,979 Sq M.M
F E-213·1
Nº 69
L. 80 M.M Total E=471
Total F=111,438 Sq M.M
F:E = 238:1
Nº 97
L 75 MM Total E=554
Total F=118,835 Sq M.M
F'E = 214 :1
Nº 88
L 79 M M Total E-591
Total F-138 341 Sq M M
F:E = 234:1
FOOD CONSUMPTION
12 684
10,653
6351
6305
5,787
4,082
4,057
4,007
1923
0
13 257
15 243
10,325
9,941
9 510
10930
9,441
9,263
7,523
6,660
5,396
3 641
1852
997
14,903
14,683
13,519
10,087
10,038
9455
8941
9161
8516
8 205
3,930
0
0
15,116
15 908
10,791
10,600
10,714
9008
9,815
10,798
10,847
6,301
4.768
2,604
1550
13 836
14.479
10,185
9,925
9,102
9,336
9 548
8 515
9 391
10 556
10,032
7,975
8,447
7,214
EGGS PRODUCED
42
34
33
30
38
28
19
25
2
42
51
49
49
51
53
52
52
47
38
13
20
18
36
51
47
46
46
52
50
50
47
36
6
4
45
54
47
54
58
55
57
59
56
46
16
9
42
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47
45
46
49
46
41
52
46
47
41
42

Water-drinking.

It has been mentioned that on hatching out water is frequently imbibed with avidity. Afterwards, unless improperly fed or neglected, the nymphs and insects avoid water. Towards the end of life, when for days together they are unable to eat and therefore to take in moisture with their food, they will search for water and remain with their mouths immersed for many minutes.

Cannibalism.

They will bite off one another's appendages if not sufficiently supplied with food. At the Manchester Museum once during vacation some stick insects were left for about 7 to 10 days without being fed. At the end of that period out of 24 specimens only 5 remained perfect, all the others having their appendages more or less mutilated, small portions of which were found lying on the floor of the jar. There were no body mutilations.

I have had two cases in which one full-grown insect was mutilated by one or more full-grown insects, although there was plenty of food in the jar at the time. Only the appendages were bitten off, and of these in one case only one leg was left perfect, when, as it could no longer feed itself, it was taken away and destroyed; while, in the other case, all the appendages were more or less bitten off, and it died of want of food.

The Excreta.

The excreta are thick and cylindrical in shape and fairly dry when ejected. The presence of eggs in the body does not in any way tend to flatten their shape, but in times of illness or approaching dissolution the excreta are flat or tape-like in appearance. This is contrary to the observations of Meissner, who states that egg ejection tended to flatten the excreta.

Protective Measures.

The nymph or insect is possibly protected from enemies by its resemblance to a stick or twig, and its habit of lying flat against a stalk, especially when very small. Also by its facility for adopting the cataleptic attitude when it slips to the ground, *not* with its appendages spread out, but all closely parallel to the body. On the other hand, it will frequently cling tenaciously to its disturber rather than avoid such.

Meissner (*op. cit.*, p. 88), in dealing with *Dixippus morosus*, considers the general lateral movement, the ejection of a brown liquid and the recurving over the back of the terminal end of the abdomen to be protective measures, but to me the lateral movement and the flow, not ejection, of the brown liquid are due to other causes and are not protective in *Carausius morosus*.

The object of the recurving of the abdomen over the back is not clear. Meissner looks upon it as a protective attitude, but Schleip does not think so. It seemed to me that, while at emergence from the egg this recurvature was very pronounced, it lessened imperceptibly, until with the egg-bearing stage it disappeared almost entirely. Schleip considers that the weight of the abdomen when full of eggs keeps it in a straight position and prevents the recurving.

Duration of Life.

Table VI, already referred to, gives the average number of days lived during the First Period as 136; but omitting the two abnormal cases of 171 and 174 days respectively, and adding the days for seven other insects under observation, viz. 127, 138, 130, 130, 123, 123, and 117, we get a normal average of 131 days with a range of 27 days (117–144), and an exceptional range of 57 days (117–174).

The average duration of life during the Second Period, according to the Table, is 207 days; but omitting the abnormal results shown by Nos. "Orig.," 18, 22, 159, 94 and 65, we obtain a normal average of 239 days with a range of 142 days (187–329).

Generally speaking, about two-fifths of the insect's lifetime is spent in the First or Preparatory Period, and three-fifths in the Second or Reproductive Period.

Death.

When ill or dying a sticky brown liquid occasionally issues from the mouth, and when the nymph or insect is asphyxiated (in the fumes of cyanide of potassium) the liquid almost invariably flows out. Excepting under these circumstances I have not found any traces of this discharge.

Variation.

Weismann, from a study of the variation of a parthenogenetic organism, *Cypris reptans*, concluded ("Germ-Plasm," 1893, p. 344) that forms reproduced in this manner varied but little. He explained this comparative constancy on the ground that the union of male and female cells in sexually produced forms provided the material for variation, and that, therefore, in the absence of the male cell, greater stability in character resulted. Warren has made observations on parthenogenetically reproduced specimens of *Daphnia magna*, and found (Proc. Roy. Soc. lxv., 1899, p. 155) that the variation shown by them was very considerable. In consequence of the divergent views on the variability of parthenogenetic forms it seems desirable to accumulate evidence on the subject, and the observations made during this study of the life-history of *Carausius morosus* are offered as a contribution towards that end.

The observations made are summarised in the following table, giving the maximum, minimum, range, average, standard deviation and co-efficient of variation for each character observed. The two latter are calculated on the method advocated by Karl Pearson ("Grammar of Science," 2nd ed., p. 387).

Table XVI.—Summary of Variations.

Particulars of Observations.	Min.	Max.	Range.	Average.	Standard Deviation.	Co-efficient of Variation.
Oviposition: Eggs produced per insect	253	712	459	513	95·76	18·66
Oviposition: Eggs produced per mm. length of insect	3·6	9·2	5·6	6·5	1·23	18·92
Size of Egg: Length in mm.	2·3	3·5	1·2	2·8	·16	5·68
Incubation: Number of days	137	297	160	165	21·85	13·24
Nymphs on hatching out: Length in mm.	6·5	13	6·5	10·5	1·34	12·7
Increase in length of Nymphs in mm. during first 24 hours	0	6	6	2·7	1·8	66·66
Increase in length of Nymphs in mm. up to and at 1st moult	7	12·75	5·75	9·9	1·23	12·42
Increase in length of Nymphs in mm. at 2nd moult	6	9	3	7·5	·77	10·2
Increase in length of Nymphs in mm. at 3rd moult	7·5	10	2·5	9	·75	8·3
Increase in length of Nymphs in mm. at 4th moult	10	13·5	3·5	11·7	·87	7·43
Increase in length of Nymphs in mm. at 5th moult	12	18	6	14·1	1·22	8·65
Increase in length of Nymphs in mm. at 6th moult	14	20	6	16·4	1·68	10·24
Length of full-grown insects of one parent in mm.	72	86	14	80·1	2·85	3·55
Duration of Life: Number of days	275	469	194	361	40·48	11·21

The variation in colour, which is not capable of measurement, is also very well marked. The original specimen, of which all the subsequent progeny formed the material on which my observations are based, was a not very dark green. The offspring have exhibited all variations of colour from a very pale green to a speckled fawn colour. As a discontinuous variation there appeared at intervals a few very dark speckled brown, almost black; three of these were isolated and the 1237 eggs dropped by them were kept separate. The accommodation at my disposal was only sufficient to rear to the adult state some 475 of the nymphs which hatched from these eggs. Of this number only eight were of the very dark colour of the parents, the remainder being various shades of green and fawn. The hereditary tendency to transmit the dark colour, although certainly present, is evidently weak.

The insects forming the subject of these observations have been reared under as uniform conditions as it was possible to get, so that the effect of environment is eliminated as a possible factor in the variation observed.

The amount of variation as brought out in the table is considerable; whether it is greater or less than in the sexually produced forms of the same insect, if any, can only be established when a similar series of observations on the latter have been carried out.

Summary of Observations.

The observations were made under a regulated temperature varying from 56° to 64° F. (13° to 18° C.).

The insects are of a lethargic disposition, feign death when disturbed, and support themselves by their claws assisted by their pads, which do not act by surface tension.

In colour they vary from a light fawn to a dark green; very dark brown almost black is rare. During life the colour barely changes.

Incubation in the boxes varied from 137 to 297 days, equal to a range of 160 days; 52·7% of nymphs hatched out in 141 to 160 days, and 32·3% in 161 to 190 days. Placed on garden mould the hatching out commenced 16 days sooner, *i. e.* in 115 days, with a somewhat similar average range.

The insects were parthenogenetic, and only one specimen, obviously an infirm female, failed to produce eggs. One male was found and there is a possibility of its being degenerated; it had no contact with any of the females under observation.

The length over all of the egg capsules varied from 2·3 to 3·2 mm., average 2·8 mm. Under 2·6 mm. long they did not hatch out. The fertility of the eggs was found to be 81·5%.

Eggs are first dropped 12 to 24 days (average 16·5 days) after the last ecdysis; they are neither laid nor shot out, but simply dropped.

The average egg production was found to be 513 per insect, the highest total reached by one insect being 712. There appeared to be no correlation between the size (length of the insect) and the quantity of eggs produced.

The nymphs emerged by pushing off the cap of the egg and *appeared* to come out pronotum first, and not head first. The length of the nymphs on hatching out varied from 7·5 to 12·5 mm., average 10·5 mm. Almost invariably on hatching out they were eager for a drink, but not keen to eat. At the end of 24 hours their average length was 13·3 mm. From the time of hatching out the nymphs grew at the rate of ·35 to ·7 mm. per day, for an average of 21 days, with a total increase of 3 to 5·5 mm. This is the only period during which the nymphs grow without shedding the skin.

The nymphs fast from 2 to 6 days pevious to the actual moulting. The ecdyses were performed by the nymph hanging head downwards, the skin splitting from the pronotum upwards, when gravity did the rest. There were in all the cases observed six ecdyses for each insect. The increase in length at every ecdysis was so marked that it was possible to ascertain by measurement the stadium in which the nymph or insect might happen to be.

The length of the full-grown insects varied from 72 to 86 mm. (exclusive of the antennae), average 80·1 mm., equal to a range of 14 mm. The progeny from eggs dropped late in life attained to a greater length than that from eggs dropped early in life.* The body length increased six-fold; the antennae increased in the same total ratio; but the increase in the various segments was more and less.

With the exceptions named the nymphs and insects

* It is noteworthy that Elkind states that in *D. morosus* the eggs are smaller during the earlier stages of production than later on (*op. cit.*, p. 14).

were fed on ivy leaves. Their food consumption doubled after every ecdysis. Except when hatched out the nymphs did not care for water, and only towards the end of life, when they were unable to eat, did they drink with avidity.

The average duration of life was 136 days for the First or Preparatory Period (*i. e.* from hatching out to the 6th moult), and 225 days for the Second or Reproductive Period; in other words, the insect spends two-fifths of its life in preparing for the following three-fifths.

The results here detailed demonstrate very clearly that parthenogenetically produced organisms do vary considerably, and support the observations made by Warren rather than those of Weismann.